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Language and Reading Progress of Young Deaf and Hard-of-Hearing Children

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Abstract

We examined the language and reading progress of 336 young DHH children in kindergarten, first and second grades. Trained assessors tested children's language, reading, and spoken and fingerspelled phonological awareness in the fall and spring of the school year. Children were divided into groups based on their auditory access and classroom communication: a spoken-only group ($n = 101$), a sign-only group ($n = 131$), and a bimodal group ($n = 104$). Overall, children showed delays in language and reading compared to norms established for hearing children. For language, vocabulary standard scores were higher than for English syntax. Although delayed in language, children made expected gains based on hearing norms from kindergarten to second grade. Reading scores declined from kindergarten to second grade. Spoken-only and bimodal children had similar word reading and reading comprehension abilities and higher scores than sign-only children. Spoken-only children had better spoken phonological awareness and nonword reading skills than the other two groups. The sign-only and bimodal groups made similar and significant gains in ASL syntax and fingerspelling phonological awareness.

Language and literacy development are related areas that can be adversely affected by childhood hearing loss (Lederberg, Schick, & Spencer, 2013). Reported language and reading outcomes of children who are deaf or hard of hearing (DHH) vary from study to study. Some research suggests that developments such as newborn hearing screening, early intervention, and the use of cochlear implants and digital hearing aids have resulted in DHH children developing age-appropriate language and reading skills in elementary school (Sarant, Harris, & Bennet, 2015; Tomblin, Oleson, Ambrose, Walker, & Moeller, 2018). Others have found both language and reading to be delayed (Kyle & Harris, 2011; Tobey et al., 2013). These conflicting findings may be due to challenges of doing research with a heterogenous low-incidence population. Some studies include DHH children who range widely in age, thus obscuring developmental changes. Others include only a subsection of the population (e.g., children with cochlear implants (CIs) or those identified early) or only measure spoken language outcomes.

The present study adds to the literature in two ways. First, we examine the development of language and literacy skills as children begin to learn to read. Specifically, we describe how skills change in comparison to norms across a school year (longitudinally) and from kindergarten to second grade (cross-sectionally). Our goal was to determine when and if DHH children's skills differ from hearing children's during this critical time period. Second, our large ($n = 336$) diverse sample allowed us to compare the development of language and literacy skills of three groups of DHH children: those who had auditory access to, and were acquiring spoken language only; those who were unimodal visual learners and were acquiring sign language; and those who had auditory access to spoken language and visual access to sign language and were acquiring both (whom we label

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bimodal in this article). Based on theoretical and empirical evidence, we hypothesized that development may differ for these three groups.

Theoretical Model

The Simple View of Reading (SVR) (Hoover & Gough, 1990; Tunmer & Chapman, 2012) served as our framework for understanding reading development. The SVR posits that reading is a product of two major components: word identification and linguistic comprehension. Word identification requires the (hearing) reader to manipulate the sublexical structure of words by decoding letters into spoken phonemes and assembling these into words. Readers can then map the decoded words onto their knowledge of the semantics and syntax of language to comprehend print. The SVR model suggests that the development of reading, defined as word reading and reading comprehension, is based on children's language and phonological awareness abilities.

Researchers agree that SVR can serve as a framework for literacy development of DHH children but differ on whether the model developed for hearing children applies to all DHH children. The qualitatively similar hypothesis developed by Paul and colleagues (Paul & Lee, 2010; Trezek et al., 2011) posits that reading requires knowledge of spoken language and that DHH children develop reading the same way as hearing children do but at a slower pace. Other researchers (Hoffmeister & Caldwell-Harris, 2014; Pettito et al., 2016) believe that DHH children use alternative visually based skills (i.e., sign language, sign phonology, fingerspelling) to learn to read. Yet others posit a third hypothesis—that both views are true, but for different DHH children depending on their acquisition of spoken and/or signed language (Lederberg et al., 2013; Miller, 2002).

DHH children differ on their language learning as a function of their language input and their speech perception abilities (Lederberg et al., 2013). Those exposed to sign in school and/or at home acquire sign language because they encounter no sensory barriers to visual language. On the other hand, speech perception abilities will determine the acquisition of spoken language. Because of cochlear implants and digital hearing aids, many, but not all, DHH children have sufficient speech perception abilities to acquire spoken language. Children who are not exposed to sign language will acquire only spoken language. DHH children who are in signing environments and can perceive spoken language may acquire both spoken and signed language and can be considered bimodal–bilingual.

Based on both reading theory and previous research, we hypothesized that DHH children's early reading abilities would be closely related to phonological awareness and language abilities, but the nature of these skills would be different for these three groups. We found support for this hypothesis when we examined the structure of language and literacy skills for these 336 young DHH children using confirmatory factor analyses (Lederberg et al., 2019). In the group who were only acquiring sign, reading was strongly related to children's fingerspelling phonological abilities and bilingual (ASL and signed English) language abilities and only moderately related to spoken phonological awareness. In the group who were only acquiring spoken language, reading was strongly related to spoken phonological awareness and moderately related to spoken language abilities. For the group of bimodal–bilingual DHH children, reading was strongly related to both fingerspelling and spoken phonological awareness, as well as their bilingual (ASL and English) language abilities. The results supported the hypothesis that DHH children in these different groups learn to read using different skills (English, ASL, spoken phonological awareness, fingerspelling) and underscore the importance of examining the development of these individual skills. In order to have a sufficient sample to conduct factor analyses, the previous study examined language and literacy skills of the kindergarten and first and second graders as a single group and only used fall scores in the analysis. The current study extends this research by examining longitudinal changes in language and literacy skills from fall to spring, as well as analyzing cross-sectional differences between kindergarten, first and second graders. We describe development and group differences for 13 measures of language and literacy skills to give a nuanced picture. We also describe development using normative data to determine how DHH children's functioning compares to expectations based on hearing norms. The following review of research briefly summarizes relatively recent language and literacy outcome studies of young DHH children between approximately 5 and 9 years of age with specific attention to those that report change over time.

Language of Young DHH Children

Much of recently published research focuses on spoken language outcomes of children with CIs (see Ruben, 2018 for a review). We divide these studies by language outcome measure, and report differences, when available, among children who differ by communication and/or by language.

Global Language

Authors of these studies administered developmental language assessments that sampled a number of different language domains such as the Reynell Developmental Language Scales (Reynell & Gruber, 1990) or administered multiple assessments and reported composite language scores. Some authors have reported delays, often along with a wide range of achievement. Tobey et al. (2013) evaluated the receptive and expressive spoken language of 160 implanted children for three consecutive years. At the 4-year (mean CA 6–4 years) and 6-year (mean CA 8–4 years) post-implant follow-up, the mean composite standard scores (SS) were 76.4 and 77.6, respectively, with a range from 69.6 to 94.7. Although children were delayed, they made, on average, expected progress over time, evidenced by the stable mean standard score. Hay-McCutcheon et al. (2008) followed a group of 30 children with CIs between ages 1.5 and 10 years and found that almost all scored a year or more below age norms; by 9 years of age, the average language age of the sample was 7.9 years.

In contrast, some researchers have reported age-appropriate development. Sarant et al. (2015) assessed the spoken language of 44 8-year-old children with CIs and reported a mean SS of 92.5, well within the average range (85–115). Tomblin et al. (2018) compared the spoken language (and literacy) outcomes of 108 hard-or-hearing (HH) children with a group of hearing controls. At age 5, the HH children scored significantly lower than the hearing group, but by age 8 the children with mild and moderate losses had scores similar to the hearing group. These children made more progress than expected and "closed the gap" with their hearing peers. On the other hand, children at both ages with severe losses scored lower than the hearing group and the other HH children.

Of the studies described, two (Hay-McCutcheon et al., 2008; Tobey et al., 2013) included participants who used a combination of spoken and signed communication. Neither group of researchers reported data separately on children based on their differences in communication. In their review of research on language outcomes, Fitzpatrick and colleagues (Fitzpatrick et al., 2016) concluded that there is, as yet, insufficient evidence through well-controlled studies to determine whether using a combination of spoken and signed communication influences language outcomes of DHH children.

Vocabulary

Several studies report on DHH children's vocabulary status, but few have documented growth during the early school years. In one of the few large studies Connor, Hieber, Alexander Arts, and Zwolan, (2000) assessed expressive and receptive vocabulary growth of children with CIs, 66 of whom used spoken and signed communication, while 81 used spoken language only. At a mean age of approximately 7 years, the average expressive and receptive vocabulary age was delayed by about 3 years for both groups. Receptive vocabulary growth was about half that of hearing norms (0.45 years of growth per year) and did not differ by communication group. Expressive vocabulary growth (0.70 years of growth per year) was similar for both groups of children but with considerable variability among participants. Hayes, Geers, Treiman, and Moog, (2009) conducted a longitudinal study of receptive vocabulary growth of 65 children with CIs between 3 and 9 years of age, attending an intensive auditory–oral program. Children achieved an initial SS of 61 but made greater than expected annual gains of almost 8 points per year resulting in an average SS of 81 at 8 years of age. Cupples, Ching, Crowe, Day, and Seeto, (2013) assessed 101 5-year-old DHH children and reported an average receptive vocabulary percentile score of 27. They too reported a large range; some children knew only 4 words while others knew 112.

Some studies indicate that young children with CIs achieve vocabulary standard scores within the average range. Geers, Moog, Biedenstein, Brenner & Hayes, (2009) examined the vocabulary of 153 children 5–7 years of age and reported mean vocabulary standard scores of 91 and 86 for expressive and receptive vocabulary, respectively; between 50 and 58% of children received standard scores within 1 SD (85–115) of test norms. Fitzpatrick, Crawford, Ni & Durieux-Smith, (2011) found DHH 4–5-year-olds had an average SS of 91, within the average range, but significantly below the average SS of 115 achieved by their hearing peers.

Harris and her colleagues conducted studies that included children who sign, who only use spoken language and who use both. Harris, Terlektsi & Kyle, (2017a) found that DHH children began school delayed and made only about a third of the progress of their hearing peers over a 2-year period. Harris, Terlektsi & Kyle (2017b) collected data from a new sample of children and found that this more recent cohort of DHH children had higher vocabulary scores than those in their longitudinal study but still lagged 2 years behind their hearing peers.

The studies by Connor et al. (2000) and Harris et al. (2017a) included in their sample DHH children who used spoken language and children who signed. Connor et al. reported no differences between these groups in progress over time, while Harris et al. found that children who used spoken language had higher scores than those who used sign. In short, reports on vocabulary vary by study with several indicating that DHH children score within the average range and others reporting delays compared to hearing peers.

Syntax

Children of signing Deaf parents acquire the syntax of sign language in a manner similar to that of hearing children acquiring the syntax of a spoken language (Lillo-Martin & Pichler, 2006). DHH children of hearing parents typically have parents who are novice signers, and many primarily acquire sign on school entry. Enns and colleagues (Allen & Enns, 2013; Enns & Herman, 2011) found that preschool and elementary DHH children's mastery of ASL structures increased with age and that children with signing parents (regardless of hearing status) outperformed, at all ages, those whose parents did not use sign.

For children acquiring spoken language, morpho-syntax can be difficult to acquire because many essential features are unstressed and nonsyllabic and therefore difficult to hear. There is ample documentation of delays in the acquisition of the syntax of spoken languages by DHH students between the late preschool and early elementary years. Geers, Nicholas & Sedey, (2003) found that the DHH children between ages 7–11 and 9–11 years scored between 2 and 3 standard deviations (SD) below the norms on tests of receptive English syntax. Geers et al. (2009) reported that only 33 and 40% of kindergarteners scored within 1 SD of their hearing age-mates in receptive and expressive English morpho-syntax, respectively. Hay-McCutcheon et al. (2008) reported that the 30 kindergarten children with CIs in their study all scored below the 50th percentile on a test of English morpho-syntax. Duchesne, Sutton & Bergeron, (2009) examined syntax acquisition of 15 children with CIs between the ages of 5 and 8 years and reported that 35% scored within normal limits (i.e., within 1 SD) on comprehension of syntactic constructions, while 42% scored within 1 SD on comprehension of morphemes.

Hay-McCutcheon et al. (2008) reported no differences between children who used spoken and/or sign communication, but Geers et al. (2003) reported that children who primarily used spoken communication scored higher on expressive English syntax than children who used sign. In brief, our knowledge of ASL syntax acquisition in elementary-aged children is limited. English syntax acquisition is delayed for many DHH children including those who have auditory access to spoken vlanguage.

Reading of Young DHH Children

Historically, median reading scores for DHH students at all grade levels were reported to be below the norms for hearing students (Karchmer & Mitchell, 2011) although research with HH children and those who have CIs shows that many children are achieving within the average range (see Mayer & Trezek 2018 for a review). While there are a number of published studies of reading, most include children within a very wide age range (e.g., Johnson & Goswami 2010). We briefly review studies of DHH children within our target age range (5–9 years).

Kyle and Harris (2011) compared the development in word reading of DHH (CA = 5.8 years) and hearing beginning readers (CA = 5.0 years), assessing them three times over a 2-year period. The authors matched the two groups on word reading ability at the beginning of the study. Eleven DHH children used spoken language while 13 used sign. Both groups made similar progress in word reading during the first year; however, the DHH children made half the progress as the hearing children in the subsequent year. Harris et al. (2017a) compared the reading progress of a slightly older cohort of 41 DHH children, ages 6.6 and 8.4 years, matched on single-word reading with hearing controls. Eighteen DHH children used spoken language while 26 used sign. Over a 2-year period, the DHH children made gains of 13 months in both single-word reading and reading comprehension, while the hearing children made gains of 31 and 24 months, respectively. Thus, in both these studies, DHH children lost ground to their hearing peers as they grew older. In contrast, Tomblin et al. (2018) found that HH children with mild and moderate hearing loss made reading progress similar to the hearing control group between ages 5 and 8 years. However, the children with severe hearing loss, who had print knowledge similar to hearing peers at age 5, were significantly behind both the hearing and other HH children in reading comprehension by age 8.

Some researchers have reported that a considerable percentage of children with CIs achieve reading scores within the average range. Dillon and Pisoni (2006) and Geers (2003) examined word reading and reading comprehension of DHH children with CIs, between 8 and 9 years of age, and included in their sample children who used spoken language and spoken and signed communication. Dillon and Pisoni reported that 70% of the children received standard scores within 1 standard deviation (SD) of test norms, while Geers reported that 52% of children received standard scores within 1 SD of the test norms.

Phonological Awareness in Young DHH Children

In order to learn to read, hearing children must be sensitive to the sublexical structure of words so they can learn to map letters to spoken phonemes. This requires the development of phonological awareness. Spoken phonological awareness involves the ability to analyze and manipulate words into their component sounds. DHH students who have auditory access are able to develop spoken phonological awareness skills. James et al. (2005) reported that mean scores of 7- to 10-year-old DHH children with CIs were higher than chance and showed improvement over 12 months. Most researchers find that DHH children score lower on these skills when compared to hearing norms and matched hearing peers. Harris and Beech (1998) examined spoken phonological awareness skills of 44 kindergarten and first grade children, of whom 32 used spoken language and 12 used sign. Although children made progress between fall and spring, their scores remained, on average, 1 SD below the test norms. Kyle and Harris (2011), Nittrouer, Caldwell, Lowenstein, Tarr & Holloman, (2012) and Cupples et al. (2013) all reported that DHH kindergartners scored below comparison groups of hearing children on spoken phonological awareness tasks. In contrast, James, Rajput, Brinton & Goswami, (2008) found that children who received CIs between 2 and 4 years of age achieved phonological awareness skills similar to hearing peers. Knowledge of spoken phonological awareness might also occur through a visual communication modality. Results of longitudinal studies of French-speaking children between kindergarten and second grade showed that by second grade, children who had received consistent and early exposure to cued speech had phonological awareness scores similar to a hearing comparison group (Colin, Leybaert, Ecalle & Magnan, 2013; Colin, Magnan, Ecalle & Leybaert, 2006). Kyle and Harris (2010) suggest that speechreading, another visual avenue, can help DHH children acquire the phonological code for spoken language. Children who do not have auditory access to spoken language may develop only limited spoken phonological awareness skills. Fingerspelling may be an alternative to spoken phonological awareness for these children because, similar to spoken phonology, it can be used to manipulate and access the sublexical structure of printed words. Fingerspelling, which consists of a manual alphabet representing the English print alphabet, is a natural part of ASL and many other sign languages. Fluently fingerspelled words contain some syllable structure depicted by a sign-like movement or envelope, while chunking or coarticulation of frequently co-occurring letter sequences aids comprehension (Brentari, 1998). Research with signing DHH adults shows that fingerspelling ability contributes significantly and independently to reading fluency (Stone, Kartheiser, Hauser, Pettito & Allen, 2015) and may serve as a means of retaining print in short-term memory to assist with decoding (Sehyr, Petrich & Emmorey, 2016). In the present study, we assessed fingerspelling phonological abilities through imitation of fingerspelled words, blending fingerspelled letters into fingerspelled words, and elision, i.e., creating a new word by deleting a fingerspelled letter(s) from a fingerspelled word. The latter two were designed to be analogous to spoken phonological awareness tasks (see Measures). Lederberg et al. (2019) found that fingerspelling and reading were highly correlated in the current sample, demonstrating the potential importance of fingerspelling to reading.

The Present Study

We know surprisingly little about the language and literacy development of DHH children during elementary school, especially for those who do not have CIs and are not solely acquiring spoken language. The present study builds on the previous findings of Lederberg et al. (2019), in which multigroup confirmatory factor analyses established across-group measurement equivalence for the assessments used in this research project. The factor structure indicated that the assessments were equally valid indicators of the proposed underlying constructs of language, reading, and phonological awareness across the three groups of children (spoken-only, sign-only, bimodal). This allowed a comparison of the groups' performance on these three constructs. The language construct reflected the children's spoken language abilities for the spoken-only group but bilingual (ASL and English) abilities for the bimodal and sign-only groups. The three groups had equivalent mean language ability or proficiency. Spoken-only and bimodal children had better reading abilities than sign-only children, with no differences between the former two groups. Spoken-only children had better spoken phonological awareness abilities than bimodal children, who had better abilities than sign-only children.

While providing an overall picture of DHH children's functioning, there were limitations to the previous study. Only fall raw scores were analyzed, and sample size requirements of confirmatory factor analyses led us to include kindergarten, first and second graders as one group. The present study extends our previous work and examines within-year gains (fall to spring) as well as differences across grades and language groups on each of the multiple measures of language and reading. We have two specific research questions. First, what is the status (i.e., level of functioning) of young DHH children's language and reading compared to the norms for hearing children? Second, how do language and reading change over a school year and from kindergarten to second grade, and do status and progress differ by group: spoken-only, sign-only, or bimodal?

Methods

Participants

Three hundred and thirty-six deaf and hard-of-hearing (DHH) children participated in this study. Children had to have a hearing loss (Better Ear-Pure Tone Average, BE-PTA >25 dB); be enrolled in kindergarten, first or second grade; and be between the ages of 5 and 9 years to be included. Children with severe disabilities (defined as the presence of autism and severe visual or cognitive impairment) were not included. We included children with mild disabilities (identified as such from teacher report). We received permission from the University IRBs and from most schools to notify parents rather than require individual written consent. We therefore were able to assess all children who met our eligibility criteria in most schools.

Children attended 103 different classes in 40 schools located in nine states in the United States and one Canadian province. A majority of children (87.5%) attended self-contained classrooms in local elementary programs or in schools serving only DHH children. The remaining 12.5% of children attended general education classrooms with hearing peers.

Groups Children were divided into three groups based on their auditory access to spoken language and availability of sign language in the classroom. We determined that children had auditory access to spoken language if they were able to identify some referents of spoken words presented through audition alone on the *Early Speech Perception Test* (ESP; Moog & Geers, 1990, see Measures). Signed language was available for those children whose teachers signed. These two dimensions resulted in the following three groups:

Spoken-only ($n = 101$). Children had auditory access to spoken language and their teachers and parents used only spoken language.

Sign-only ($n = 131$). Children did not have auditory access to spoken language. Their teachers signed with or without using spoken language. While these children may have been exposed to spoken language, they were visual learners because they had little or no speech perception even with typical amplification based on their ESP performance.

Bimodal ($n = 104$). Children had auditory access to spoken language and teachers signed with or without using spoken language. These children were in the same classrooms as the sign-only children but differed from them in their auditory access.

Teachers and examiners (i.e., those who administered study assessments) completed ratings of children's language abilities that indicated our categorization accurately divided the sample. They confirmed that almost all children in the spoken-only and sign-only groups used either spoken language *or* sign. In the spoken-only group, one child knew some sign language that teachers rated severely limited. In the sign-only group, five children knew some spoken language but teachers rated their abilities as severely limited. Bimodal children varied in language use, with 74% using both spoken and signed language, 14% preferring to only use spoken language, and 14% preferring to only use sign. Teachers of children who signed (i.e., sign-only and bimodal) reported using ASL only (62%), using both ASL and signed English (27%), and only signed English (11%). Thus, the majority of sign-only and bimodal children were in classrooms where ASL was the language of instruction.

Table 1 provides the demographic, audiological, and background characteristics of the three groups of children. Group differences were examined with chi-square analyses for categorical data and ANOVAs for interval data. Groups did not differ in terms of grade, gender, age of diagnosis of hearing loss, or cognitive abilities. However, they differed in their race/ethnicity. The sign-only group had more White children than the other groups; spoken-only group had more African–American children and fewer Hispanic children than the other groups. The spoken-only group had more children with CIs and better speech articulation abilities than the other groups. The sign-only group contained more children with at least one DHH parent than the other groups. Children in the three grades did not differ significantly for any background/demographic measure (see Table S1. Supplemental tables and figures are online).

Measures

Speech and cognitive measures were used to describe the children's abilities. We assessed ***speech perception*** with the ESP (Moog & Geers, 1990). Using an acoustic hoop, examiners asked children to select referents from a closed set of pictures for spoken words. Consistent with the test manual, performance was classified into four categories: 1 = no pattern perception (0 correct), 2 = pattern perception (discriminated syllabic structure), 3 = some word identification (selected correct referents for 33–65% of words), and 4 = consistent word identification (selected correct referents for more than 65% of words). Children in the latter two categories were judged to have auditory access to spoken language. We assessed ***speech articulation*** with the *Arizona Articulation Proficiency Scale–3* (Fudala, 2000). Children were asked to supply a spoken word for a series of pictures. Speech pathology graduate students scored responses from recordings. Raw scores were converted to degree of speech articulation impairment based on age norms. We assessed ***nonverbal IQ*** with the DAS-II Matrices subtest (Elliott, 2007). Children were asked to select a picture that fits a matrix pattern. Raw scores were converted to T-scores. The normative mean equals 50 with a SD of 10.

Language We assessed ***vocabulary*** with the *Expressive One-Word Picture Vocabulary Test-4* (EOWPVT; Martin & Brownell, 2011) which required children to name pictures of increasingly unfamiliar items. We accepted both spoken and signed words (ASL or English). Responses were judged to be correct based on the manual and a list of acceptable signs developed by the researchers. We assessed ***receptive English syntax*** with the Elaborated Phrases and Sentences subtest of the *Test of Auditory Comprehension of Language-3* (TACL; Carrow-Woolfolk, 1999). Children had to select the correct picture after being given a sentence. Assessors administered items in spoken English and/or in sign. When signing, assessors signed the sentences in English word order but did not sign English morphemes (e.g., −ed, −s). They accompanied sign with spoken language based on their knowledge of children's preferences. We assessed ***expressive spoken English syntax*** with the Word Structure subtest of the *Clinical Evaluation of Language Fundamentals-4* (CELF; Semel, Wiig

Table 1 Demographic characteristics by group

Variable	Spoken	Bimodal	Sign	Total
Mean age in years (SD)	6.6 (1.0)	6.6 (0.9)	6.8 (1.0)	6.7 (1.0)
Grade: kindergarten (%)	50	38	34	40
First	28	36	34	33
Second	23	26	31	27
Ethnicity: Hispanic	23	39	30	31
Race: white	44	55	63	55
Black	26	17	11	17
Asian	7	3	8	6
Other	14	20	8	13
Home language				
Spoken English only	69	30	14	36
ASL only	0	9	41	19
ASL + spoken English	3	30	28	21
Spoken language only—not English	12	9	7	9
Bilingual spoken	15	8	2	8
Deaf or hard-of-hearing parent	7	23	50	29
Timing of hearing loss				
Congenital	52	76	82	65
Acquired	11	4	5	6
Don't know	35	21	27	28
Audiological technology				
Unilateral CI (with or without HA)	20	25	14	19
Bilateral CI	35	10	7	15
Hearing aid(s) only	45	56	47	51
None	1	3	30	13
Mild additional disability (any)	25	30	19	25
Attention	8	8	5	7
Cognitive	4	4	2	3
Motor	13	11	6	10
Emotional/behavior	2	5	4	4
Differential ability scale T score M (SD)	46.7(8.1)	46.7 (9.1)	45.9 (8.1)	
Early speech perception				
No pattern perception	0	0	93	39
Pattern perception	0	0	7	1
Some word identification	1	1	0	2
Consistent word identification	99	98	0	58
Level of speech articulation impairment				
None	53	25	—	37
Mild	24	13	—	18
Moderate	21	28	—	25
Severe	2	34	—	20

Note. All numbers are percentages, except where noted otherwise. Percentages may not sum to 100 due to rounding or missing data.

& Secord, 2004). This test uses cloze-set items to elicit expressive morphology. Examiners administered stimuli to children who signed using simultaneous communication. Children had to produce the word with the correct morphology, using either speech, English signed morphemes, or fingerspelling. We assessed ***receptive ASL syntax*** with the *ASL Receptive Skills Test (Revised)* (Schick, 2013). Children watched a recording of a model signing 32 ASL sentences and selected a picture from a closed set of three to six pictures for each item. Sentences assessed complex syntax such as verb agreement, classifiers, and topicalization.

Reading We assessed reading with three subtests of the Woodcock–Johnson (WJ) Tests of Achievement III-NU (Woodcock et al., 2007). We assessed ***single-word reading*** with *Letter-Word Identification* (*WJ Word ID*). We required students to identify letters with spoken or fingerspelled names and single printed words with spoken and/or signed words. We assessed ***nonword reading*** with *Word Attack* that requires children initially to express the sounds of single letters and then to decode nonsense words. We accepted Visual Phonics and vocal approximations as a way to represent spoken phonemes. We assessed ***reading compre-***

hension with *Passage Comprehension* (*Pass comp*) that measure comprehension of single sentences starting with matching symbols or rebuses to a picture, followed by matching short phrases to a picture, and finally, requiring children to provide the missing word in a sentence. We accepted spoken and/or signed words.

Phonological awareness (PA) We assessed **spoken PA** with the Sound Matching and Blending subtests of *Comprehensive Test of Phonological Processing* (CTOPP; Wagner, Torgesen & Rashotte, 1999). ***Sound Matching*** required children to select the picture that matched the initial or final sound of the target picture and did not require speech. We assumed sign-only children would use either their knowledge of the spoken phonology of depicted words or visual (speechreading) information to take this test. ***Blending*** required children to combine spoken sounds to form spoken words. Assessors administered the directions using each child's preferred language and communication, but all items were delivered in spoken language.

We assessed **Fingerspelling PA** with three subtests of the *Fingerspelling Ability and Phonological Awareness Test* (FS-PAT; Schick, 2012). Items on the FS-PAT were presented via a laptop with stimuli signed by a native Deaf signer. ***Fingerspelling Imitation*** (F. Imitation) required children to imitate a series of fingerspelled real words of increasing length and difficulty (first item = car, last item = caterpillar). ***Fingerspelling Blending*** (F. Blend) and ***Elision*** (F. Elision) subtests were modeled after items on the CTOPP blending and elision subtests. For ***F. Blend***, children were required to blend handshapes into a real word; it included eight items of increasing difficulty (first item = t-oy; last item = g-r-a-ss-h-o-pp-e-r, with hyphens showing the segmentation). The Deaf signer paused slightly between the segments and spatially separated the segments. For ***F. Elision***, the Deaf signer fingerspelled the word and instructed the child to delete a specific fingerspelled segment or letter. It included eight items of increasing difficulty (first item = popcorn without–corn, last item = strain without–r).

Procedures

Our test battery included tests developed for hearing children. Standard basal and ceiling rules were used for all tests. We adapted these tests for use with signing children by having a team of experts that included native Deaf and hearing signers meet and establish standard protocols. They then created recordings of standardized directions, items (e.g., sentences on the TACL), and a list of acceptable signed responses (all available from the second author). Examiners were teachers or speech–language pathologists who were fluent in the children's language. The examiners were extensively trained in administration procedures and the accommodations based on children's language and communication (e.g., identifying acceptable signs for vocabulary assessments) during a 2-day training workshop. Examiners who administered the tests to signing children were provided model recordings of a deaf examiner. Prior to administering tests to children, they had to administer the tests to the fourth author, a native signer, for approval.

Examiners administered tests individually in a quiet room. Children used their typical personal hearing technology. Examiners started testing with the ESP to determine if the child had access to spoken language. The two assessments that required spoken language skills (speech articulation, CTOPP blending) were only given to spoken-only and bimodal children. Initially, all children received the expressive spoken English syntax (CELF-WS) test, but testing was discontinued for sign-only children because they consistently scored at floor. Only those children who attended classrooms where teachers used sign received the ASL and fingerspelling assessments.

We maintained scoring integrity in multiple ways. All assessments were recorded. Examiners double-checked their live scoring with these recordings. Graduate students re-scored items for 20% of children randomly chosen (blocked by group). Interrater agreement ranged from 0.88 to 0.99. Graduate students independently calculated standard scores twice and conferenced with a third researcher to resolve discrepancies. They independently entered scores twice into the database, and discrepancies were resolved by a third researcher. Internal reliability for each test was calculated for each group for fall and spring. As is evident in Table S2, reliability values were high (between 0.73 and 0.97) and similar across groups.

Statistical Analyses

Dependent Variables

For the assessments normed for hearing children, we analyzed children's standard scores because effects of time and grade are more clinically interpretable than raw scores. Stable standard scores for time or grade would suggest that DHH children were learning as much as expected based on the norms. An increase in standard scores would suggest that DHH children were learning more than expected, while a decrease would indicate that they were learning less than expected. Because the ASL receptive syntax and fingerspelling tests did not have normative data, we used percentage of items answered correctly as the dependent variable in all analyses for these tests.

Because total raw scores can provide information about changes in the number of correct test items, indicating that children are learning the skills measured by the test, we have graphed total raw scores (number of items correct). For the three Woodcock–Johnson tests, we graphed W scores which are scaled total scores that place children on an equal interval metric useful for measuring growth using a common unit (Woodcock et al., 2007) (see Figures S1–S4 online).

We calculated the total sample's average standard score (SS) and the percentage of children who scored within or above 1 standard deviation (SD) of the normative mean (e.g., 85 or above; 7 or above). We used this criterion because these standard scores are considered to be in the average range according to test manuals. For reference, 85% of hearing children in the norming samples score within this range. Assessments for vocabulary, single-word reading, nonword reading, and reading comprehension had a normative SS mean of 100 and SD of 15. Assessments for English receptive and expressive syntax and spoken PA sound matching and blending had a normative SS mean of 10 and a SD of 3.

For each assessment, using SAS PROC MIXED (SAS Institute Inc., 2014), we conducted a repeated measure ANOVA with Time (fall, spring) as the repeated measure and Grade (kindergarten, first, second grade) and Group as between-subjects factors. For vocabulary, English receptive syntax, single-word reading, nonword reading, and reading comprehension, Group had three levels (spoken-only, bimodal, sign-only). For the English expressive syntax and spoken PA blending, Group had two levels (spoken-only and bimodal). For the ASL receptive syntax and the fingerspelling tests, Group had two levels (bimodal and sign-only). We adopted $\alpha = 0.01$ as the criterion for statistical significance to minimize Type 1 error because all tests were correlated with each other. Post Hoc tests (Tukey's HSD) were conducted when the main effect of Grade or Group was significant. Simple effects tests were conducted to examine the effect of Time for each Grade or Group when there was Time x Grade or Time x Group interaction. We also calculated the effect sizes (g; Hedges, 2007) as the model estimated mean difference adjusted for residual error at fall. Similar to Cohen's d, Hedges' g is the model-based number of standard deviations that two measures differ (controlling for all other effects in the model).

Results

The groups scored in the average range for nonverbal IQ with no group differences. As expected, the groups differed on their speech abilities (see Table 1). Tables S3–S14 (available online) present the statistical results of the ANOVAs and follow-up tests. Because of the volume and complexity of the data, and to improve readability, we summarize these results in Table 2. We describe only those effects that were statistically significant.

Language

Table 3 displays language score means, SDs, and the percentage of the sample scoring within the average range. Tables S2–S4 display model results.

Vocabulary (EOWPVT)

The total sample had a standard score of 83.2, with 44% of children scoring within or above 1 SD of the normative mean (i.e., above 85). Across the school year, vocabulary standard scores for the total sample increased from 81.2 to 84.9, $g = 0.25$. Kindergarteners increased their scores from 80.8 to 86.2, $g = 0.46$. First graders increased scores from 81.9 to 85, $g = 0.19$. In second grade, standard scores were flat. Thus, vocabulary gains across the school year were greater than the gains which would have been expected in the normative sample in kindergarten and first grade and similar to gains expected in the normative sample in second grade.

Despite the gains occurring during the school year, there were no significant effects for grade. Children in all three grades started the school year with standard scores around 80. The graph of raw scores displayed in Figure S1 (available online) shows a continuous increase in the number of correct words with time (i.e., from fall to spring and from grade to grade) and also shows that growth was similar for the three groups. The only exception were sign-only kindergarteners who started with low vocabulary scores but are caught up with the other two groups by the end of their kindergarten year.

Syntax

English receptive syntax (TACL) The total sample had an average standard score of 5.8 with 37% of the children within 1 SD of the normative mean. Scores increased from 5.6 to 6.0 across the school year, $g = 0.17$. Children in the spoken-only (mean = 6.2, $g = 0.45$) and bimodal (mean = 6.4, $g = 0.50$) groups scored similar to each other but higher than children in the sign-only (mean = 4.9) group. Figure S1 (online) shows that each group increased the total correct items with time.

English expressive syntax (CELF-WS) Spoken-only and bimodal children had an average standard score of 2.7, more than 2 SD below the normative mean. Only 11% of children scored within 1 SD of the normative mean. Children in the spoken-only group showed gains from fall (mean = 2.7) to spring (mean = 3.5, $g = 0.28$), but there was no main effect of Group. Figure S1 shows that children increased the total number of correct items from fall to spring but both groups scored close to floor.

ASL receptive syntax Across the school year, scores increased from 61.9 to 69.9% correct, $g = 0.53$. Kindergarteners scored lower (mean = 56.0%) than first graders (mean = 65.0%, $g = 0.60$) who scored lower than second graders (mean = 79.3%, $g = 0.90$.) As evident in Table 2 and Figure S1, scores of children in the sign-only and bimodal groups were very similar and showed steady improvement from fall to spring and between grades. With an average of 82.0% correct in the spring, many second graders were close to ceiling.

Language results summary On vocabulary and receptive and expressive English syntax, DHH children were delayed compared to test norms. Vocabulary was a strength compared to children's knowledge of syntax. English expressive syntax was severely delayed with almost all children scoring well below the average range. Overall, children showed improvements on standard scores from fall to spring, though effect sizes were small, with the exception of vocabulary learning by kindergarteners ($g = 0.46$). Standard scores were similar across grades. Spoken-only and bimodal children had similar scores on vocabulary and syntax tests. Sign-only children had similar vocabulary scores to the other two groups but lower scores on receptive English syntax ($g = 0.45$–0.50). On the ASL test, the sign-only and bimodal children showed remarkably similar and consistent improvement across time and grade.

Reading

Table 4 displays reading standard score means, SDs, and the percentage of the sample scoring within the average range. Tables S5–S7 display model results.

Single-Word Reading (WJ Word ID)

The total sample had an average score of 91.2 with 67% of the children scoring within 1 SD of the norm (at or above 85). Kindergarteners (mean = 95.7) had higher scores than second graders (mean = 84.9, $g = 0.65$). Only kindergarteners significantly increased their scores from fall (mean = 94.5) to spring (mean = 97.1), $g = 0.14$. Overall, spoken-only (mean = 96.1, $g = 0.65$) and bimodal children (mean = 92.9, $g = 0.45$) scored higher than sign-only children (mean = 85.9), with no difference between the former two groups. Spoken-only children increased their standard scores from fall (mean = 94.7) to spring (mean = 97.6, $g = 0.15$). W scores increased for all three groups (see Figure S2).

Nonword Reading (WJ Word Attack)

The total sample had an average score of 82.2 with 46% of children scoring within 1 SD (at or above 85). Standard scores decreased from fall (mean = 83.5) to spring (mean = 81.0, $g = 0.19$). Kindergarteners (mean = 93.2) had higher standard

Table 2 Summary of analysis results: time, grade, and group effects

Construct	Test	Time		Grade		Grade * Time		Group		Group * Time	
Language	Vocabulary SS	F < S	(0.25)			KF < KS	(0.46)				
						1F < 1S	(0.19)				
	Eng. rec. syn SS	F < S	(0.17)					Spoken > sign	(0.45)		
								Bimodal > sign	(0.50)		
	Eng. exp. syn SS	F < S	(0.14)							Spoken_F < spoken_S	(0.28)
	ASL rec. syn %	F < S	(0.53)	K < 1	(0.60)						
				1 < 2	(0.90)						
				K < 2	(1.50)						
Reading	Single-word SS			K > 2	(0.65)	KF < KS	(0.14)	Spoken > sign	(0.65)	Spoken_F < spoken_S	(0.15)
								Bimodal > sign	(0.45)		
	Nonword SS	F > S	(0.19)	K > 1	(0.73)			Spoken > bimodal	(0.75)	Sign_F > sign_S	(0.44)
				K > 2	(1.01)			Spoken > sign	(1.85)		
								Bimodal > sign	(1.10)		
	Reading comp. SS	F > S	(0.19)	K > 1	(0.90)			Spoken > sign	(0.59)	Sign_F > sign_S	(0.33)
				1 > 2	(0.42)			Bimodal > sign	(0.39)	Bimodal_F > bimodal_S	(0.21)
				K > 2	(1.32)						
Spoken PA	Sound match SS							Spoken > sign	(0.88)		
								Bimodal > sign	(0.60)		
	Blending SS	F < S	(0.31)					Spoken > bimodal	(0.86)	Spoken_F < spoken_S	(0.53)
Fingerspelling	Imitation %	F < S	(0.58)	K < 1	(0.79)						
				1 < 2	(1.03)						
				K < 2	(1.82)						
	Blending %	F < S	(0.50)	K < 1	(0.60)						
				1 < 2	(0.97)						
				K < 2	(1.57)						
	Elision %	F < S	(0.56)	1 < 2	(1.05)	1F < 1S	(0.72)				
				K < 2	(1.49)	2F < 2S	(0.80)				

Note. Effect sizes (Hedges' g) in parentheses. SS = standard score. % = percent correct. Analyses were from a 2 × 3 × 3 repeated measure ANOVA (fall, spring; grades K-2; sign, spoken, bimodal).

Table 3 Means and standard deviations by time, grade, and group on language measures

Test	Score	Group	Kindergarten		First grade		Second grade		Total	% ≥ 85/% ≥ 7
			Fall	Spring	Fall	Spring	Fall	Spring		
			M (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	
Vocabulary (EOWPVT)	Standard score	Spoken	82.8 (16.1)	85.5 (16.6)	80.4 (12.5)	82.8 (13.1)	79.5 (10.2)	78.9 (11.2)	82.3 (14.2)	43%
		Bimodal	82.1 (13.4)	86.2 (14.8)	83.8 (11.2)	86.5 (15.2)	78.2 (14.6)	81.7 (14.9)	83.5 (14.1)	44%
		Sign	76.6 (16.3)	86.9 (16.6)	81.2 (18.2)	86.0 (17.7)	84.0 (11.3)	85.4 (11.3)	83.6 (15.8)	45%
		Total	80.8 (15.4)	86.2 (15.9)	81.9 (14.6)	85.3 (15.6)	81.0 (12.2)	82.6 (12.7)	**83.2 (14.8)**	
		% ≥ 85	37%	55%	36%	49%	41%	41%	**44%**	
Eng. rec. syntax (TACL)	Standard score	Spoken	6.5 (2.9)	6.8 (3.2)	5.5 (2.6)	5.9 (2.6)	5.7 (2.5)	6.7 (2.7)	6.2 (2.9)	40%
		Bimodal	6.6 (3.1)	7.0 (3.2)	6.1 (2.6)	5.8 (2.8)	6.0 (2.9)	6.8 (2.4)	6.4 (2.9)	47%
		Sign	4.7 (2.9)	4.8 (2.8)	4.4 (2.6)	5.2 (2.7)	5.1 (2.8)	5.7 (2.6)	4.9 (2.7)	28%
		Total	5.9 (3.1)	6.2 (3.2)	5.2 (2.7)	5.6 (2.7)	5.5 (2.7)	6.3 (2.6)	**5.8 (2.9)**	
		% ≥ 7	43%	44%	34%	34%	29%	37%	**37%**	
Eng. exp. syntax (CELF-WS)	Standard score	Spoken	3.1 (2.6)	3.9 (3.4)	2.2 (2.1)	3.2 (2.9)	2.6 (2.2)	3.2 (2.4)	3.1 (2.8)	13%
		Bimodal	2.5 (2.9)	2.3 (2.2)	2.1 (2.5)	2.2 (2.6)	2.1 (3.1)	2.3 (3.0)	2.3 (2.7)	9%
		Total	2.9 (2.7)	3.2 (3.0)	2.1 (2.3)	2.6 (2.7)	2.3 (2.7)	2.7 (2.8)	**2.7 (2.7)**	
		% ≥ 7	11%	16%	6%	11%	7%	14%	**11%**	
ASL rec. syntax (Schick, 2013)	Percent correct	Bimodal	51.7 (15.3)	60.4 (14.8)	60.3 (14.5)	69.9 (13.5)	73.6 (13.2)	79.5 (9.8)	64.5 (16.5)	
		Sign	50.6 (18.5)	61.4 (17.9)	61.0 (18.0)	69.3 (17.8)	78.7 (9.6)	83.9 (9.4)	66.9 (19.3)	
		Total	51.1 (17.0)	60.9 (16.4)	60.7 (16.4)	69.6 (15.8)	76.7 (11.3)	82.0 (9.7)	**65.8 (18.1)**	

Note: EOWPVT test norm: $M = 100$; SD = 15. TACL and CELF-WS test norms: $M = 10$; SD = 3. The bold numbers are means and SDs of the whole sample on each language measure, as well as the percentage of the whole sample scoring at or above 1 SD of the normative test mean. The percentage can be compared with 85% of the hearing norming sample who scored at this level. All children were administered the vocabulary and English receptive syntax test. Only sign-only and bimodal children were administered the ASL receptive syntax test.

Table 4 Means and standard deviations by time, grade, and group on standard scores of reading measures

Test	Score	Group	Kindergarten		First grade		Second grade		Total	% ≥ 85
			Fall	Spring	Fall	Spring	Fall	Spring		
			M (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	
Single-word (WJ Word Id)	Standard score	Spoken	95.6 (16.5)	101.2 (14.1)	97.4 (14.5)	98.1 (13.9)	89.6 (11.0)	89.7 (9.0)	96.1 (14.4)	81%
		Bimodal	96.2 (15.1)	98.3 (14.3)	91.6 (14.3)	90.3 (13.1)	90.3 (15.9)	88.1 (16.3)	92.9 (15.0)	72%
		Sign	91.7 (14.4)	91.6 (13.8)	86.0 (14.1)	86.4 (14.4)	80.2 (15.8)	78.6 (16.7)	85.9 (15.6)	53%
		Total	94.5 (15.4)	97.1 (14.6)	90.8 (14.9)	90.7 (14.5)	85.5 (15.4)	84.3 (15.7)	**91.2 (15.7)**	
		% ≥ 85	76%	81%	66%	69%	49%	53%	**67%**	
Nonword (WJ word attack)	Standard score	Spoken	103.7 (15.2)	102.7 (14.0)	97.4 (14.3)	96.6 (13.4)	91.3 (11.7)	91.7 (11.2)	98.7 (14.4)	83%
		Bimodal	97.8 (20.5)	95.0 (17.6)	80.3 (16.1)	81.3 (15.5)	79.6 (20.7)	77.4 (21.1)	85.6 (19.9)	49%
		Sign	81.4 (14.1)	73.6 (12.7)	66.1 (12.9)	62.7 (14.8)	62.2 (18.6)	55.6 (21.2)	66.0 (17.6)	13%
		Total	96.6 (18.8)	90.4 (19.3)	78.8 (19.0)	78.0 (20.0)	74.7 (21.5)	71.2 (24.3)	**82.2 (22.2)**	
		% ≥ 85	67%	60%	34%	36%	36%	37%	**46%**	
Reading comp. (WJ Pass. Comp.)	Standard score	Spoken	97.0 (12.8)	96.6 (15.7)	86.4 (15.5)	85.4 (12.0)	81.6 (8.3)	81.1 (8.3)	90.1 (14.5)	65%
		Bimodal	96.6 (13.0)	94.0 (16.6)	84.5 (14.2)	80.9 (14.3)	79.0 (15.9)	77.3 (14.7)	86.4 (16.4)	56%
		Sign	95.1 (12.3)	89.3 (14.2)	79.6 (17.0)	75.9 (14.9)	71.9 (13.0)	68.6 (16.4)	80.4 (17.3)	43%
		Total	96.3 (12.6)	93.3 (15.7)	83.0 (15.9)	80.1 (14.4)	76.4 (13.5)	74.4 (15.1)	**85.2 (16.7)**	
		% ≥ 85	86%	75%	47%	36%	29%	25%	**53%**	

Note. WJ subtest norms: $M = 100$; SD = 15. The bold numbers are means and SDs of the whole sample on each reading measure, as well as the percentage of the whole sample scoring at or above 1 SD of the mean of the normative test mean. The percentage can be compared with 85% of the hearing norming sample who scored at this level.

scores than first graders (mean = 78.4, $g = 0.73$) and second graders (mean = 73.0, $g = 1.01$). Spoken-only children (mean = 98.7) had higher standard scores than bimodal (mean = 85.6, $g = 0.75$) and sign-only children (mean = 66.0, $g = 1.85$). Bimodal children had higher standard scores than sign-only children, $g = 1.10$. Scores of sign-only children declined from 68.0 to 64.2 across the school year, $g = -0.44$. Figure S2 shows the spoken-only children made steady increases in nonword reading across time and grade. Bimodal children made smaller gains. Sign-only children made slower progress and their W scores declined in second grade.

Reading Comprehension (WJ Passage Comprehension)

The total sample had an average score of 85.2 with 53% of children scoring within 1 SD. Scores decreased from 86.5 to 83.8

Table 5 Means and standard deviations by time, grade, and group on spoken phonological awareness measures

Test	Score	Group	Kindergarten		First grade		Second grade		Total	% ≥ 7
			Fall	Spring	Fall	Spring	Fall	Spring		
			M (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	
Sound match (CTOPP)	Standard score	Spoken	7.8 (2.1)	8.3 (2.1)	7.4 (2.3)	7.7 (2.9)	6.3 (2.2)	6.7 (0.6)	7.7 (2.3)	74%
		Bimodal	7.2 (3.3)	7.2 (3.3)	6.3 (2.5)	6.5 (2.2)	6.4 (2.5)	6.3 (2.4)	6.7 (2.8)	54%
		Sign	4.3 (3.7)	6.1 (3.1)	4.5 (2.3)	4.9 (2.1)	5.0 (2.5)	4.8 (2.6)	4.9 (2.9)	29%
		Total	6.4 (3.4)	7.2 (3.0)	5.8 (2.6)	6.1 (2.6)	5.7 (2.5)	5.7 (2.4)	**6.3 (3.0)**	
		% ≥ 7	67%	66%	32%	34%	38%	40%	**50%**	
Blending (CTOPP)	Standard score	Spoken	4.8 (4.9)	9.4 (3.4)	8.0 (4.0)	9.4 (2.0)	7.0 (3.3)	7.9 (2.7)	7.6 (4.1)	70%
		Bimodal	4.4 (4.5)	4.8 (5.2)	3.2 (4.0)	3.7 (4.2)	4.3 (4.0)	4.4 (3.6)	4.1 (4.3)	34%
		Total	4.6 (4.7)	7.3 (4.9)	5.3 (4.6)	6.1 (4.4)	5.5 (3.9)	6.0 (3.6)	**5.8 (4.5)**	
		% ≥ 7	42%	66%	44%	60%	46%	48%	**52%**	

Note. CTOPP subtest norms: M = 10; SD = 3. All children were administered the sound match test. Only spoken language and bimodal children were administered the blending test. The bold numbers are means and SDs of the whole sample on each spoken phonological awareness measure, as well as the percentage of the whole sample scoring at or above 1 SD of the mean of the normative test means.

across the school year, $g = 0.19$. Kindergarteners (mean = 94.8) had higher scores than first graders (mean = 81.6, $g = 0.90$) who scored higher than second graders (mean = 75.4, $g = 0.42$). Spoken-only children (mean = 90.1, $g = 0.59$) and bimodal children (mean = 86.4, $g = 0.39$) scored higher than sign-only children (mean = 80.4), with no difference between the former two groups. Sign-only children decreased their scores from fall (mean = 82.4) to spring (mean = 78.3, $g = 0.33$) as did bimodal children (fall mean = 87.8; spring mean = 85.0, $g = 0.21$). In contrast, spoken-only children's scores were stable across the school year (fall mean = 90.4, spring mean = 89.8; $g = 0.02$). Figure S2 shows that while all three groups increased their reading comprehension W scores over time, the gap between their scores and those of the normative sample increased with grade.

Reading Results Summary

While most kindergarten DHH children scored within the average range on all three reading skills tested, standard scores declined with grade, with large effect sizes. Reading skills of kindergarteners were similar to the norming sample, with 75% having spring reading comprehension scores within the average range. In contrast, only 25% of second graders scored within the average range in spring. The three groups differed widely in reading skills. Children in the sign-only group scored lower than children in the bimodal and spoken-only groups on all three tests of reading, with medium to large effect sizes. Bimodal and spoken language children differed on nonword reading, but not on single-word reading or reading comprehension. By spring of second grade, children in all three groups had stronger word reading than reading comprehension skills. By second grade, although scores declined with grade, spoken-only and bimodal children still had close to age-appropriate word reading skills, while sign-only children scored 1 SD below normative means. All three groups scored below hearing norms in reading comprehension.

Spoken Phonological Awareness (PA)

Table 5 displays spoken PA standard score means, SDs, and the percentage of the sample scoring within the average range or higher. Tables S8–S10 display model results.

Sound matching (CTOPP sound matching) The total sample had an average score of 6.3 with 50% of children scoring within or above the average range. Sign-only children (mean = 4.9) scored lower than spoken-only (mean = 7.7, $g = 0.88$) and bimodal children (mean = 6.7, $g = 0.60$), with no difference between the latter two groups.

Sound blending (CTOPP blending) Bimodal and spoken-only DHH children had an average score of 5.8 with 52% of children scoring within the average range. Scores increased from fall (mean = 5.1) to spring (mean = 6.6), $g = 0.31$. Spoken-only children (mean = 7.6, $g = 0.86$) had higher scores than bimodal children (mean = 4.1) and increased their scores from fall (mean = 6.2) to spring (mean = 9.0), $g = 0.53$. Figure S3 shows that both groups increased their blending scores from fall to spring, but the gap between their scores and those of the hearing norming group increased with grade.

Spoken PA results summary The majority of spoken-only children had spoken phonological awareness skills within the average range and performed equally well on sound matching and blending. Bimodal children performed much better on sound matching than sound blending. Sign-only children scored more than 1.5 SD below the test norms on sound matching.

Fingerspelling PA

Table 6 displays percentage of items correct for the sign-only and bimodal children. Tables S11–S13 display model results.

FS imitation Children increased their scores from 34.0 to 45.3% over the school year, $g = 0.58$. Kindergarteners had lower scores (mean = 22.3%) than first graders (mean = 39.0%), $g = 0.79$, who had lower scores than second graders, (mean = 61.2%), $g = 1.03$. Figure S4 shows the steady increase in percentage correct items for sign-only and bimodal children with time.

FS blending Children increased their scores from 17.0 to 26.7%, over the school year, $g = 0.50$. Kindergarteners (mean = 9.0%) scored lower than first graders (mean = 20.0%, $g = 0.60$) who scored lower than second graders (mean = 37.4%, $g = 0.97$).

Table 6 Means and standard deviations by time, grade, and group on fingerspelling phonological measures

Test	Score	Group	Kindergarten		First grade		Second grade		Total
			Fall	Spring	Fall	Spring	Fall	Spring	
			M (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)
F. Imitation	Percent correct	Bimodal	15.8 (17.6)	28.8 (22.9)	28.9 (22.0)	41.6 (21.0)	54.4 (23.1)	73.4 (16.5)	37.7 (27.3)
		Sign	17.1 (16.4)	27.4 (21.2)	36.3 (24.9)	49.7 (25.1)	56.8 (20.8)	62.6 (20.8)	40.9 (26.8)
		Total	16.5 (16.9)	28.0 (21.9)	32.9 (23.8)	45.8 (23.4)	55.9 (21.6)	67.0 (19.7)	**39.5 (27.0)**
F. Blending	Percent correct	Bimodal	6.3 (13.0)	14.0 (19.5)	16.8 (18.7)	18.0 (17.9)	27.0 (21.6)	43.2 (21.7)	19.5 (21.4)
		Sign	3.5 (7.7)	11.9 (19.2)	16.2 (19.5)	28.1 (27.6)	35.5 (24.7)	43.6 (23.2)	22.6 (25.1)
		Total	4.7 (10.5)	12.8 (19.2)	16.5 (19.0)	23.4 (23.9)	32.1 (23.7)	43.4 (22.4)	**21.3 (23.6)**
F. Elision	Percent correct	Bimodal	2.4 (11.4)	7.0 (14.2)	4.3 (8.2)	18.0 (22.9)	25.0 (28.5)	41.7 (35.1)	14.9 (24.7)
		Sign	4.4 (13.3)	4.9 (11.8)	8.5 (15.6)	20.1 (26.3)	25.4 (27.5)	37.1 (32.9)	16.2 (25.1)
		Total	3.5 (12.4)	5.8 (12.9)	6.5 (12.8)	19.1 (24.6)	25.2 (27.7)	39.0 (33.6)	**15.6 (24.9)**

Note. All means are percentage of correct items. The bold numbers are means and SDs of the whole sample on each fingerspelling phonological measure.

Figure S4 shows the steady increase of percentage correct items for both groups with time.

FS elision Children increased their scores from 11.3 to 19.9% over the school year, $g = 0.56$. Kindergarteners did not increase their scores. First graders increased their scores from 6.5 to 19.1%, $g = 0.72$. Second graders increased their scores from 25.2 to 39.0%, $g = 0.80$. Kindergarteners scored lower (mean = 4.7%) than second graders (mean = 31.9%), $g = 1.49$, but not first graders. First graders (mean = 12.8%) scored lower than second graders, $g = 1.05$. As is evident in Figure S4, while most kindergarteners could not do this task, there was a steady increase in percentage correct responses from first grade fall through second grade spring.

FS summary Both sign-only and bimodal children made similar and steady gains on these three tasks. Imitation was the easiest task, while elision was the hardest. By second grade, children did not reach ceiling for any of the fingerspelling tests.

Discussion

The purpose of this research was to describe the language and literacy of a large sample of young DHH children and examine their progress longitudinally over the course of a school year, cross-sectionally from grade to grade, as well as across groups. We purposefully included DHH students who had different access to language; thus we included children who had access to spoken or sign language only and also those who had access to both. The latter group particularly tends to be little studied. We discuss key findings arranged by the major constructs: language, reading, and spoken and fingerspelled phonological awareness.

Language

While children started in kindergarten delayed compared to the hearing test norms, they made greater than expected gains during the school year, as shown by increases in standard scores in all areas of language from fall to spring. Substantially more children achieved within the average range in vocabulary than in English syntax. In vocabulary and English syntax, children made expected progress between kindergarten and second grade, compared to age-based hearing norms. Children who had access to spoken language made gains in expressive English syntax, though they scored well below age norms. Those students who had access to sign made steady gains in ASL syntax.

Our sample achieved an average expressive vocabulary standard score of 83, lower than the standard score of 91 reported by Geers et al. (2009), but similar to the average score of 81 achieved by children 8 years of age as reported by Hayes et al. (2009). Less than 50% of the children scored within the average range (standard scores 85–115) somewhat worse than the 58% reported by Geers et al. Children in all three grades made progress during the course of the school year, but kindergartners and first graders made greater than expected progress (based on test norms), while second graders made expected progress. Our sample showed better outcomes than that of Connor et al. (2000) who reported that, although vocabulary growth was positive, growth was less than expected based on test norms. In first and second grades, our total sample showed annual gains of 3–5 standard score points, which was substantial, but less than the 8 standard scores in annual gain reported by Hayes et al. (2009). It is important to note that children did not differ on vocabulary knowledge based on their group. Despite greater than expected progress during the school year, the gap between the DHH students and their typical hearing peers remained wide across grades. This suggests that elementary-aged DHH children may be losing the gains they made during the school year over the summer as has been shown for preschoolers (Scott, Goldberg, Connor & Lederberg, 2019).

English syntax was the weakest area for all children as reported also by other researchers (Geers et al., 2003; Hay-McCutcheon et al., 2008). The children in our sample were 1.5 SD below age norms in receptive English syntax and 2.5 SD below in expressive English syntax. Access to spoken language (in this case spoken English) was an advantage in learning receptive English syntax, reflected in the similar and higher scores of spoken-only and bimodal children compared to the sign-only children. However, all three groups showed some improvement (shown by raw scores) in receptive English syntax over the school year. While progress might be expected of the children who had auditory access to English, the sign-only children without such access also mastered additional items. We speculate that these children may be developing bilingual skills and learning to understand English word order from adults around them who use contact sign.

Consistent with findings by other researchers (e.g., Geers et al., 2003, 2009), access to spoken language was not sufficient for acquiring age-appropriate expressive English syntax. Only 11% of children in the spoken-only and bimodal groups scored within the average range on the CELF. However, the spoken-only children made more than expected progress from fall to spring, while the bimodal children made expected progress. The raw scores show that the spoken-only children mastered about five additional items during the school year; the bimodal children mastered less than one additional item. These differences may reflect a different instructional focus across classrooms; teachers may spend more time in direct or indirect instruction on English syntax in spoken-language-only classrooms.

Both groups of children who had access to sign (bimodal and sign-only) showed substantial improvement in ASL receptive syntax from fall to spring and from grade to grade. In fact, by the end of second grade, children were close to ceiling on this assessment. There was no effect of group, suggesting that access to spoken language did not appear to inhibit the bimodal children's learning of ASL syntactical structures.

Reading

Reading, to a much larger extent than language, was affected by both grade and group. Kindergarteners showed age-appropriate skills in all three areas assessed: single-word reading, nonword reading, and reading comprehension. At kindergarten, these tests assess children's emerging literacy skills, namely, alphabetic knowledge (letter-name, letter-sound) and the ability to understand concepts depicted by rebuses (not printed words). Other researchers (e.g., Cupples et al., 2013) have also reported that hearing loss and language delay does not prevent acquisition of these early skills. The children in our sample increased their reading skills from fall to spring and from grade to grade as indicated by their W scores but made less than expected progress from kindergarten to second grade, consistent with findings of other researchers (Harris et al., 2017b; Kyle & Harris, 2011).

Group had a large effect on reading. Spoken-only children had age-appropriate nonword and single-word reading skills with 80% of children (across grades) scoring in the average range, very close to the 85% for the normative sample. Thus, spoken-only children were able to develop the knowledge of how to sound out and blend fairly complex words by second grade. Lederberg et al. (2013) suggest that phonics instruction may be particularly effective with DHH children who have auditory access to spoken language because letters can serve as visual support for their learning of spoken phonology. Despite strength in word reading, spoken-only children showed a decline of 16 standard points in reading comprehension from kindergarten to second grade.

Bimodal children had weaker nonword reading skills than spoken-only children, with 50% scoring within the normative average range. Despite differences in phonological and spoken language skills, bimodal and spoken-only children had similar word reading and reading comprehension achievement. These results are in contrast to researchers that report differences favoring children using spoken language (Dillon & Pisoni, 2006) but similar to Geers (2003) who found no effect of communication modality on reading skills for children with CIs.

Sign-only children were delayed in all three reading skills and showed greater delays than spoken and bimodal children. These children's difficulty with nonword reading would be expected given their lack of access to spoken language. The fact that their W scores increased over time suggests they may use visual and kinesthetic means to acquire knowledge of spoken phonemes (Haptonstall-Nykaza & Schick, 2007; Kyle, Campbell & MacSweeney, 2016; Kyle & Harris, 2010). Sign-only children also showed lower achievement in word reading and reading comprehension compared to both bimodal and spoken-only children. Given that the three groups did not differ in overall language ability (Lederberg et al., 2019), and that bimodal and sign-only children were exposed to the same sign input in the classroom, it appears that access to spoken language facilitated learning to read. Sign-only children need to learn to translate English words into ASL which is a complex process (Hoffmeister & Caldwell-Harris, 2014).

Phonological Awareness

As expected, auditory perception was an advantage for spoken phonological awareness. Spoken-only children scored within the low average range on both sound matching and blending. These results are similar to those reported by James et al. (2008) for early implanted CI children and what some researchers have found for DHH kindergarteners (Kyle & Harris, 2011; Nittrouer et al., 2012). The bimodal children were similar to the spoken-only children on sound matching but scored considerably lower in sound blending. Their poorer performance on blending might have been due to speech production issues. Although the sign-only children received standard scores about 3 SD below the test norms on sound matching, the raw scores for this group at each grade level were greater than 0 and increased from fall to spring. As with nonword reading, these results might indicate that sign-only children are using visual information such as speechreading and fingerspelling to identify some spoken phonemes.

This is the first study to examine developmental change in fingerspelling PA. Fingerspelling increased across the school year and grade to grade. Imitation was a relatively easy task while elision was difficult. The ability to manipulate the sublexical features of words, as shown in the blending and elision tasks, increased across time, but even second graders were correct on less than half of the items. This is worse than the spoken-only children did on the parallel task of sound blending. It may be that blending fingerspelling is a more difficult task, but it also may be a result of lack of instruction on this skill in signing classrooms. Both the sign-only and bimodal children performed in a remarkably similar manner on the fingerspelling tasks achieving similar percentage scores and showing significant growth from fall to spring and developmental differences across grades. This may suggest the bimodal children could access the sublexical features of English words through both auditory and visual means, and access to one did not seem to inhibit learning in the other.

Assessment Issues

Every researcher is faced with the issue of how to effectively and ethically assess DHH children on tests that are not specifically designed or normed for them. We chose to administer mostly standardized tests of language and reading that were well validated and widely used with hearing children because these provided us with interpretable data to examine growth over a school year and across grades. We purposefully did not administer every test to each child but assessed children on the tests that had items that were accessible to them and that they had the opportunity to acquire based on their language and communication environment. We judged it unethical to take time away from classroom instruction for assessments that were clearly invalid for specific groups of children. Thus, we did not assess the sign-only children on the spoken phonological awareness blending subtest because it required spoken responses. We assessed bimodal children on phonological awareness, because the ESP data indicated that they had auditory access to spoken English even if they were in a signing educational environment. We did not assess spoken-only children on ASL receptive syntax or fingerspelled phonological awareness, because they were not exposed to and therefore could not acquire sign or fingerspelling.

Modifying standardized tests raises questions about whether standardized scores and test norms are appropriate to use. On the other hand, administering standardized tests in one invariant manner to all DHH children raises questions about assessment validity. We believe that making some reasonable modifications to allow the range of DHH children access to the test items and ensuring that these modifications were consistently used ensured, as much as possible, that the test scores we obtained were valid (Sechrest, 2005). In order to ensure that assessments were valid for each group of children, we made standard adaptions to each test to accommodate the different language and communication access and environments, but we ensured that these adaptations were not idiosyncratic or dependent on the skill of individual examiners. We ensured that all examiners were trained to administer each test and took extreme care with scoring. Despite the variability in children's language and communication access, we obtained high inter-rater reliability for all tests for all groups. Despite these precautions, it is possible that some assessment results, such as spoken phonological blending, were influenced by children's expressive speech capabilities. However, we tested many of these validity questions for the fall time point (Lederberg et al., 2019) and found that the tests had good psychometric properties for their intended constructs and had no strong evidence of bias across groups.

Implications for further research An important finding of this study was that the bimodal children in our sample, a group seldom studied, are learning both English and ASL and making progress in both languages. However, this finding needs to be replicated with other samples of bimodal children. We need to also address how development, and perhaps instruction, in both languages influences reading development. For example, it would be informative to study exactly how bimodal children use spoken and sign language while reading. It would also be informative to study whether exposure to English-like sign facilitates reading. Another area that needs further study is the influence of fingerspelling on reading decoding for DHH children. Our previous research showed that reading was strongly related to fingerspelling (Lederberg et al., 2019) and there is some evidence that signing DHH children benefit from connecting fingerspelled words to print (Haptonstall-Nykaza & Schick, 2007). However, evidence is needed on the role of systematic instruction in this area.

We also need to explore further why children made comparatively little progress in reading comprehension. Even spoken-only children who showed close to age-appropriate language on word reading and nonword reading showed delays in reading comprehension by the end of second grade. One explanation might be that our sample displayed weak English syntax skills; the SVR suggests that both decoding and language are equally important to comprehension. Detailed analyses of reading comprehension profiles (Kyle & Cain, 2015) hold promise for understanding both the specific language skills and the level of proficiency of these skills necessary to improve outcomes.

Implications for Instruction

The documentation of language and reading status and progress indicates some areas in which we can focus instructional practice. In the area of language, although vocabulary is a relative strength, the majority of children have lexicons that are considerably smaller than their typical hearing peers. English syntax is a notable weakness even for children with access to spoken language. Systematic and intensive instruction in each of these areas is probably beneficial for all children. On the other hand, children with access to sign in the classroom appear to be making progress in ASL syntax, indicating that, when the structure of language is visual and therefore completely accessible, current instructional practices may be sufficient to ensure acquisition.

Classroom instruction and teacher talk can make a difference in children's language learning. Duncan and Lederberg (2018) examined teacher talk in classrooms and reported that explicit vocabulary instruction and teachers' reformulation of children's utterances were predictors of gains in children's vocabulary and expressive English syntax. These authors also reported that teachers were highly variable in the amount of explicit vocabulary instruction in which they engaged and that explicit morpho-syntax instruction occurred rarely. Given DHH children's delays in vocabulary and English morpho-syntax, it might be necessary for teachers to engage in explicit direct instruction and for researchers and practitioners to collaborate on developing and evaluating instructional practices in these areas.

In the area of reading, all children acquired the simple skills, such as letter naming and matching rebuses to pictures that are required at the kindergarten level, but had difficulty with word reading and comprehension that are required by the second grade. According to the SVR, reading comprehension requires both fluent decoding and linguistic comprehension (Gough & Tunmer, 1986; Tunmer & Chapman, 2012). The challenge, as always, is identifying the kind of instruction that will help DHH students make sufficient progress in both these areas. Ongoing research by the authors documenting reading instruction in classrooms should assist in identifying the interaction between instruction and children's progress in reading. Such knowledge should help determine effective teaching strategies and the amount of time children need to be engaged in different types of reading instruction.

Limitations

A limitation of this study is that we did not include a comparison group of typically hearing children and thus were only able to compare the DHH children's scores to published test norms. Because our sample is also not matched to the test sample, a comparison group matched on variables such as socioeconomic status or ethnicity would have provided more precise information on overlap, progress, and specific areas of delay in language and reading. Technically, standard scores are also not on a longitudinally consistent metric. However, the effects of standardization are likely to be small for the current short-term longitudinal design. Our sample also does not represent the larger population of DHH children; rather, we focused on children in self-contained programs. These children are likely to be those most in need of intensive instruction, but our results should not be generalized to all DHH children. Another limitation is that we only received self-reports from teachers about their use of ASL or signed English. We were not able to obtain observational or other data to confirm the kind of signing occurring in classrooms.

Although we examined differences due to time, grade, and group on several outcomes, there are many other malleable variables that influence individual children's language and reading. Other researchers, for example, have documented the effects of age of implantation, age of diagnosis and intervention, and the quality of early intervention (Dunn et al., 2013; Geers et al., 2009; Kyle & Harris, 2010; Moeller, 2000). For any single child, variables impacting language and reading will also include those related to the home (e.g., parental access to professional support, home literacy environments) and to school (e.g., quality and consistency of classroom instruction). Given the low incidence of childhood deafness, and the difficulty of examining large samples, it is likely that no single study can examine simultaneously all possible variables. It is important that readers keep in mind that the variables examined in this study are only some of the many variables that will impact children's language and reading.

Unlike some researchers, we included children whom teachers reported as having mild disabilities. Because it is possible that the presence of these disabilities may have influenced the results, we ran post hoc analyses to examine the effects of disability. Children with mild disabilities scored, on average, lower than children without disabilities. While there were main effects, disability status did not interact with time, grade, or group. Excluding children with mild disabilities changed minimally the overall means and analyses reported in this paper.

Conclusion

The positive news is that the DHH children in our sample made progress in vocabulary learning and were acquiring the syntax of either English (spoken-only and bimodal children) or ASL (sign-only and bimodal children). Thus, despite delays, children were acquiring language to which they had access in their environment. They were also developing phonological processing skills either auditorily or visually. However, for all groups, delays in reading comprehension increased in higher grades. Future research might clarify how and why classroom instruction influences these outcomes. The challenge, as always, will be to develop evidence-based instructional strategies that will lead to improvement in literacy for all children while taking advantage of their opportunities for visual and auditory access to language.

Supplementary Data

Supplementary material is available at http://jdsde.oxfordjournals.org/.

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Conflicts of Interest

No conflicts of interest were reported.

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